OBSERVATIONS ON *PINUS MAXIMARTINEZII* RZED.

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ABSTRACT

Pinus maximartinezii is a rare pinyon pine with a natural range restricted to one site in the state of Zacatecas, Mexico. Based on recent field reconnaissance, the entire distribution has been determined to be approximately 400 hectares. The species' altitudinal distribution is 1600 to 2550 meters above sea level. The population size is estimated to be approximately 2000 to 2500 mature individuals. Observations on the species' reproductive cycle and site and soil characteristics are included in this report.

RESUMEN

Pinus maximartinezii es un pino piñonero muy escaso, con una distribución natural restringido a un solo sitio en el estado de Zacatecas, México. En base a un reconocimiento reciente del sitio, se ha determinado que el área total de la población es aproximadamente 400 hectáreas. La especie crece entre 1600 y 2550 metros sobre el nivel del mar. Se estima que el numero total de individuos de edad reproductiva es entre 2000 y 2500. Este reporte incluye observaciones del ciclo reproductivo y de las características del sitio y de los suelos.

Pinus maximartinezii Rzed. is a Mexican pinyon pine reported growing only in the state of Zacatecas. One of the least known of the Mexican pines, it is considered rare and endangered because of its restricted distribution and small population size (Rzedowski 1964; Perry 1991). In fact, Styles (1993) considered it one of the most threatened of all pine species.

This species has leaves in fascicles of five, 7–11 cm in length, with 2 external resin canals. It is one of only two five-needle pinyon pines in North America. Cotyledons number from 18 to 24, a unique trait among conifers, which usually have a maximum of eighteen (Rzedowski 1964). Female cones average 15–23 cm in length and 11–13 cm in diameter, with some attaining 30 cm in length and 18 cm in diameter. The mature seed cones are similar in form and size to those of *P. coulteri* D. Don, and may reach a green weight of 1½ to

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2 kg. The cone scales are unique among pinyon pines, being very large, thickened, and extremely hard upon drying. Oleoresin monoterpene content is about 90% limonene, as in *P. pinceana* Gordon (Zavarin and Snajberk 1987). Complete descriptions of this species are given by Rzedowski (1964), and Perry (1991). This is the first report containing information on strobili development and timing.

The taxonomic classification of *Pinus maximartinezii* is still in doubt. Little and Critchfield (1969) placed it in subsection *Cembroides.* Considered a relict species, *P. maximartinezii* is most closely related to *P. pinceana* and *P. nelsonii* Shaw (Bailey and Hawksworth 1987; Malusa 1992). Because of morphological differences between *P. maximartinezii* and *P. pinceana* and the other taxa in *Cembroides,* Rzedowski (1964), and Bailey and Hawksworth (1987) suggested that a new subsection be created for these two species. Perry (1991), in his revised classification of the Mexican pines, placed both *P. maximartinezii* and *P. pinceana* in a new subsection *Pinceana.* Malusa (1992) thought both species more closely related to subsection *Gerardianae* than to *Cembroides.*

The objective of this account is to report on the distribution of *Pinus maximartinezii,* and provide new information on its reproductive cycle and the environment in which it grows. Information on the species' reproductive cycle is reported as observed in its native environment. Studies in planted trials will be important in providing more complete details on the biology of this species.

The information reported here was collected in February and June of 1993, as part of a gene conservation project in which the species' distribution was mapped, the site characterized, and individual trees selected for seed collections.

Population Size and Site Characteristics

The only known population of *P. maximartinezii* is on Cerro Piñones at the southern extreme of the Sierra de Morones, Zacatecas (21°22′N, 103°14′W) (Fig. 1), at 1600 to 2550 m. Most of the population occurs in a band from 2100 to 2300 m elevation. Elevations were measured with a mechanical pocket altimeter, and corroborated with topographic charts.

The species total range is about 400 hectares (Fig. 1). The pine grows on the eastern, southern and southwestern aspects of Cerro Piñones, but not on the mountain 1 km to the north. The range was determined by field reconnaissance and measurements on a 1:50,000 topographic chart with an electronic planimeter.

The pines comprise two subpopulations, separated by a ridge top, but not completely isolated reproductively from one another; one on the east slope, and the other on the southwestern slope. On the east slope, groups of 3 to 5 trees predominate, situated mainly in

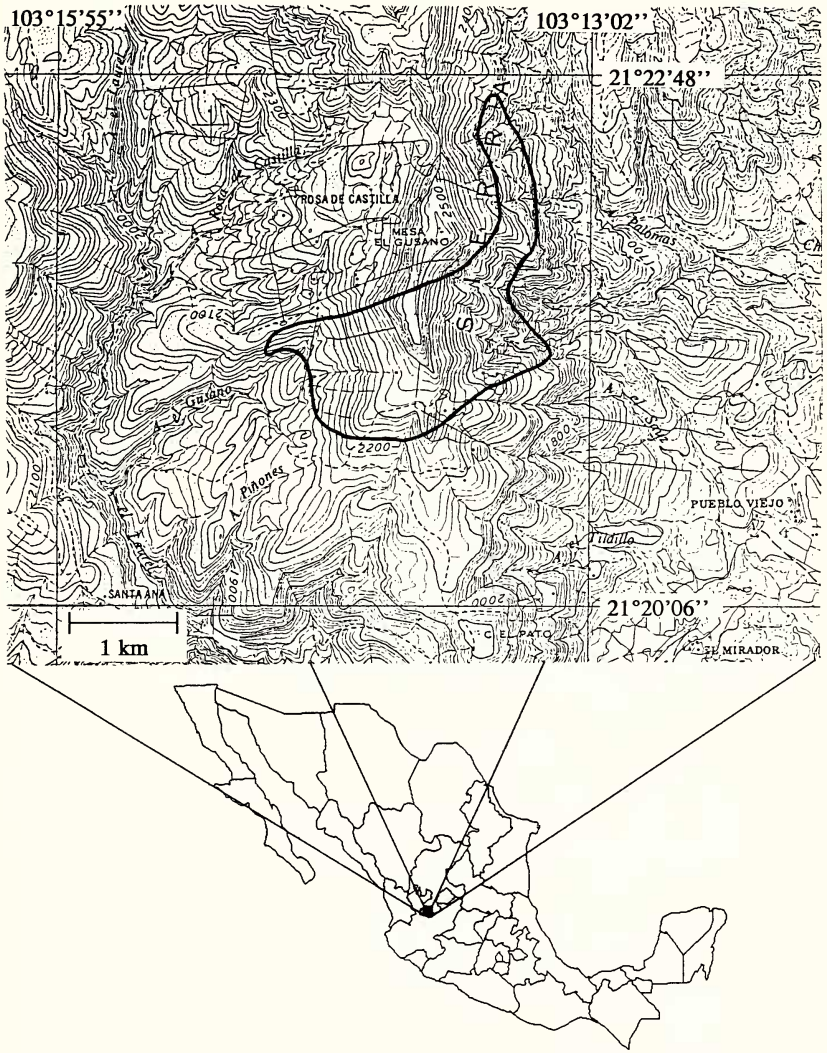

FIG. 1. Distribution of *Pinus maximartinezii* on Cerro Piñones, Zacatecas, Mexico. Based on Topographic Chart 1:50,000 Juchipila F-13-D-36, Instituto Nacional de Estadística Geografía e Informática (Mexico), 1973.

and along the draws. This spatial arrangement is probably due to past felling for grazing activities. Isolated individuals (>100 m to nearest neighbor) are widely scattered. On the southwest slope, although fewer in number, the pines are denser, with groups of 10 to 30 trees and distances of 10 to 50 m among trees. Based on our observations, the total number of mature trees is about 2000 to 2500.

The site where *P. maximartinezii* grows receives an estimated 800–900 mm annual rainfall, most of which falls in June through September (SARH 1988). Malusa (1992) called this the highest rainfall for any pinyon pine in North America. The mean annual temperature is about 17°C. Climatic estimates are based on data collected at the Juchipila, Zacatecas, meteorological station.

Soils on Cerro Piñones where the pines grow are calcareous, and limestone and gypsum outcrops are abundant on the eastern slopes, specifically along the southern ascent route. Near the northeastern extreme of the pines' extension, a loose reddish igneous rock (scoria) is scattered about the surface. Here the woody vegetation changes from pine–oak to mixed hardwoods, suggesting that *P. maximartinezii* may be restricted to the calcareous soils on the southern extreme of this mountain. According to Malusa (1992) *Pinus nelsonii, P. pinceana* and *P. johannis* Robert, other locally endemic Mexican pinyons are limited to calcareous soils.

We collected soil samples at 10 cm depth, from four places on east, west, and west-southwest slopes where the pines grow. The two eastern slope samples were sandy clays and sandy clay loams, with a pH of 7.2 and 7.5. Samples from the west and west-southwest slopes were both clay loams, with a pH of 7.0 and 6.8. Soil reactions were field tested and recorded with a pocket digital pH meter. Textures were determined in the field by the tactile method.

Reproductive Cycle

On February 17, 1993, we found two distinct female cone crops on the trees. The smaller cones were about 4–6 cm long, and 3–5 cm in diameter, apparently still growing. The larger cones appeared nearly mature (about 15–20 cm long and 10–12 cm diameter), with resin exudations beginning to appear on the cone scales. We saw no new, emerging female cones. A few very sporadic male strobili were beginning to emerge. This information on strobili development is based on observations of 100 trees growing in natural stands, which were selected for seed collection.

Four months later, on June 15, 1993, we found new female cones about 1–2 cm long and 1 cm in diameter, that had apparently just passed the receptive stage. The female cones emerge solitarily at the ends of the branches. Empty male strobili were still attached to the branches, but pollen dispersal had clearly ended across the site. Cones of the intermediate crop were now about 6–8 cm in length. The largest cones were now more completely covered with resin exudations, and the cone scale apophyses had begun to turn brown. Thus we saw three distinct cone crops on the trees at the same time, indicating a reproductive cycle spanning four growing seasons from reproductive bud initiation to cone maturity.

Reproductive bud initiations in *P. maximartinezii* probably occur between August and September. Pollination apparently is in May and/or June of the second year. The exact time lapse between pollination and fertilization is unknown, but fertilization probably occurs in either the second or third year, rather than the fourth. Cone maturation and seed dispersal take place in September and October. A similar cycle has been reported for *P. leiophylla* Shiede and Deppe, *P. torreyana* Parry ex Carr. and *P. pinea* L. (Martínez 1948; USDA Forest Service 1974; Owens and Blake 1985), and likewise for *P. chihuahuana* Engelm. (Mirov 1967; Perry 1991), which some authors consider a variety of *P. leiophylla.*

In most pine species with a three-year reproductive cycle, fertilization is twelve to fourteen months after pollination. Owens and Blake (1985) wrote that in pines with a four-year reproductive cycle, pollination takes place in the second year, but pollen tube and ovule development remain arrested for two years, with fertilization, and embryo and seed maturation occurring in the fourth year (Table 1). This is unlikely with *P. maximartinezii* because the largest seed cones were already fully elongated and nearly mature in February, eight months prior to seed dispersal, with external resin exudations, indicating that fertilization had occurred in a previous year. Apparently this species undergoes a prolonged period of cone development and maturation. Having the largest cones and seeds of the pinyon pines (and among the largest for all pines), it is possible that *P. maximartinezii* needs an extended period after fertilization to produce them because of the short 4–5 month growing season at the site where it occurs. If this is true, fertilization could occur a few weeks after pollination, in the second year, or twelve months later, in the third year (Table1). Cones would mature and disperse seeds in the fourth year.

Therefore, in June, at the time of our second field observation, the largest cones would have been in their fourth year from time of bud initiation, the 6–8 cm cones would have been third-year, and the 1–2 cm conelets second-year. Strobili development and seed dispersal dates for *P. maximartinezii* nearly coincide with those of *P. edulis* Engelm. and *P. monophylla* Torr. and Frem. in the USA (USDA Forest Service 1974).

Conservation

The remaining pines grow on private property. The landowners value them for the pine nuts, and try to conserve the mature, fruiting trees. Natural regeneration was sparse in 1993, possibly because of continued cattle grazing on the site, and a ground fire that occurred in 1989. Several old mature trees were killed by the fire, apparently their relatively thin bark unable to tolerate high temperatures.

TABLE 1. A COMPARISON OF THREE AND FOUR-YEAR PINE REPRODUCTIVE CYCLES WITH THE PROPOSED *P. MAXIMARTINEZII* CYCLE.

Three-year reproductive cycle			Four-year reproductive cycle		
Bud initiation	summer/fall	1st year	Bud initiation	summer/fall	1st year
Pollination	spring	2nd year	Pollination	spring	2nd year
Fertilization	summer	3rd year	Fertilization	summer	4th year
Seed dispersal	fall	3rd year	Seed dispersal	fall	4th year
		Pinus maximartinezii			
	Bud initiation	August/September	1st year		
	Pollination	May/June	2nd year		
	Fertilization	May/June	2nd or 3rd year (?)		
	Seed dispersal	October/November	4th year		

Because of its thin bark and extremely slow growth, *P. maximartinezii* is especially susceptible to decimation by fire and human activities. Immediate conservation measures are needed to promote establishment and survival of natural regeneration on the site. Fire prevention and control must be top priorities while studies are conducted to assess the effect of cattle grazing on natural reproduction. A gene conservation project has been initiated by the CAMCORE Cooperative, North Carolina State University, USA, and the Centro de Genética Forestal, Chapingo, Mexico. A population-wide seed collection has been completed and ex-situ conservation plantings and research trials are planned at sites in Mexico and other countries.

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It is with sadness that I report that Carlos Mar Lopez, the second author of this paper, died in an accident in November, 1994. His dedication to the research and conservation of Mexican pines was outstanding and will be greatly missed.

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